VOLUME XXXIV NUMBER 4 WHOLE NUMBER 293

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PUBLISHED MONTHLY
(*Ten numbers per year*)
April, 1940

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XXXIV, No. 4 APRIL, 1940 WHOLE No. 293

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Vol. XXXIV, No. 4 APRIL, 1940 WHOLE No. 293

THE ATMOSPHERES OF THE PLANETS*

By R. M. PETRIE

THE subject of tonight's address is one of the astronomical problems which appeals to a large number of persons; not only to those directly interested in scientific studies but also to everyone who takes an interest in extra-mundane affairs. The determination of the presence and composition of a planet's atmosphere is a necessary prerequisite to an intelligent discussion and appreciation of the possibility of life existing thereon. Thus we dismiss the airless moon as a possible abode of life while our interest in Venus and Mars, from this point of view, is stimulated with each new study of their atmospheric envelopes. In the study of planetary atmospheres the biologist, chemist and cosmogonist alike find problems of interest and observations of importance in their special fields of knowledge.

The existence of atmospheres surrounding most of the planets has been known to astronomers for many years from various lines of evidence to be discussed later. The composition of these atmospheres was, however, a mystery until a comparatively recent date. During the last decade progress has been rapid and our knowledge of the composition and approximate extent of the planetary envelopes is now for the most part, in a very satisfactory state. This advance has come about chiefly from achievements in three separate fields of science which have united to attack this problem successfully. These achievements are, in brief: (*a*) the great experimental and theoretical progress in the study of molecular (band) spectra, such as those given by oxygen, water-vapour, carbon-dioxide, the hydrocarbons and so on; (*b*) the improvements and discoveries in photographic technique

*A lecture before the Vancouver Centre, April 9, 1940.

which have resulted in the production of photographic emulsions sensitive to radiations in the infra-red region of the spectrum, making it possible to study planetary spectra in these important regions, and (*c*) the use of telescopes of great aperture and light-gathering power so that powerful spectroscopic methods of analysis could be applied to planetary spectra.

The purpose of this lecture is to invite your attention to the present state of our knowledge of the existence, extent and composition of planetary atmospheres. It is quite likely that some of the findings of modern investigators will be at variance with a cherished opinion of theory regarding certain members of the solar system. The new information is for the most part established on a firm scientific basis and is not likely to be modified save in some details and additions. The speaker will be amply repaid if some of these modern results prove to be novel to you.

Evidences for the Existence of Planetary Atmospheres

Let us first consider the facts which point to the existence of gaseous envelopes surrounding the planets. The principal lines of evidence are as follows:

(*a*) Surface appearance,
(*b*) Albedo or reflecting power,
(*c*) Twilight and refraction effects,
(*d*) Spectroscopic evidence,
(*e*) Gravitational attraction.

These lines of evidence, familiar to astronomers by the end of the nineteenth century, may now be discussed in some detail with reference to individual planets.

(*a*) *Surface Appearance.* Several of the planets, when examined through a telescope or photographed, exhibit isolated markings, streaks, and zones ephemeral in nature. These changing features cannot belong to the solid surface but must partake of the nature of clouds. The belts of Jupiter and Saturn, the occasional short-lived projections at the limb of Mars and the extremely faint and elusive markings on Venus all point to cloudy atmospheres of greater or lesser extent. The telescopic appearance of these objects may be compared with that of our moon which never exhibits any changing cloud forms, nor any softening of the sharply-defined black shadows cast

upon its harsh bright surface by mountain and ridge. Our satellite has been aptly described as a "naked rock in vacuo".

(*b*) *Albedo or Reflecting Power.* The brightness and whiteness of a planet compared with that of a perfectly reflecting screen is called its albedo and is a clue to the existence of an atmosphere. Ordinary gases are good reflectors as shown by the brightness of our sky and clouds, and the "earthshine" upon the young moon, while rocks and soil are poor reflectors. The albedos of the planets are given in Table I (column 2). From this table we see that the earth, Venus and the

TABLE I

Name	Albedo	Colour	Velocity of Escape
Moon	7%	Yellow	1.5 mi/sec.
Mercury	7%	Yellow	2.0 "
Venus	59%	White	6.5 "
Earth	45%	Blue White	7.0 "
Mars	15%	Red	3.2 "
Jupiter	44%	Yellow White	38 "
Saturn	42%	Yellow White	24 "
Uranus	45%	Greenish White	14 "
Neptune	52%	Green	13 "

major planets Jupiter, Saturn, etc., are good reflectors, while the airless bodies Mercury and the moon reflect only 7 per cent. of the light incident upon their surfaces. We would expect the above named good reflectors to have extensive atmospheres, while Mars with an albedo of 15 per cent. lies between bodies with extensive atmospheres and those devoid of such covering. Hence we expect Mars to possess an atmosphere of lesser density than Venus or the earth.

(*c*) *Twilight and Refraction Effects.* If a planet exhibits phases, such as Mercury, Venus, and Mars, a careful study of the position and appearance of the line dividing day and night (terminator) will indicate whether any light is being reflected and scattered into the geometrical shadow. This effect is noticeable here on earth, as our twilight, which allows us to receive sunlight after the sun has set below our horizon. Similar effects have been discerned on Venus and Mars. When Venus is a narrow crescent her cusps show a pronounced elongation and when she transits the sun a complete halo of scattered light is seen. When Mars is in the gibbous phase a twilight

effect on the terminator is measurable. No such phenomenon has been observed in the case of Mercury although the observations for this planet are very difficult. Twilight and refraction effects are absent from the moon, even under the extremely sensitive tests of eclipses and occultations. In the case of the giant planets the phase effect is never great enough to make this test significant.

(*d*) *Spectroscopic Evidence.* The evidence supplied by the spectroscope is very important in this problem since it allows us to identify atmospheric constituents. When light is passed through a gas the molecules produce their peculiar systems of absorption bands in the radiation, and in this way tell us of their identity. A comparison of the direct light of the sun, or that reflected from the moon, with the reflected light from a planet shows whether any new spectral features have been imposed on the radiation by passage through the planetary atmosphere. In this way atmospheres surrounding Venus, Jupiter, Saturn, Uranus and Neptune have been demonstrated while Mercury and the moon show no indications of gaseous envelopes. Curiously enough Mars also fails to show conclusive spectroscopic evidence although other lines of evidence concur in attributing an atmosphere to this body.

In considering spectroscopic evidence it must be remembered that certain elements and compounds cannot be detected in this way because their absorption features lie in spectral regions inaccessible to study, because of the absorption of radiation in passing through our own atmosphere. Thus hydrogen, helium, nitrogen, neon and argon are beyond detection by the spectroscopic method.

(*e*) *Gravitational Attraction.* Indirect evidence for or against the presence of an atmosphere may be secured from a consideration of the gravitational attraction of a planet, together with the motion of molecules in a gas. Every planet, by virtue of its surface gravity, can control velocities up to a certain critical value called the "velocity of escape". Beyond that value any object will leave the planet and escape into free space, never to return. In Table I the "escape-velocities" for the various planets are listed in column 4, while the mean molecular velocities of several gases at 0° C (freezing point) and 100° C (boiling point) are given in Table II. In order that a planet should retain a gas over a very long period, Jeans estimates that the velocity of escape must be at least *five* times the mean molecular velocity. Comparing the numerical values in tables I and II one sees that the

giant planets could retain all known gases, the earth and Venus could retain all but hydrogen while Mars would allow hydrogen and helium to diffuse rapidly into space, would experience difficulty, perhaps, in controlling water-vapour and methane and would retain the other gases. The moon and Mercury having weak gravitational fields

TABLE II
Mean Molecular Velocities

Name	at 0°C.	at 100°C.	Name	at 0°C.	at 100°C.
Hydrogen	1.1 mi/sec.	1.3 mi/sec.	Chlorine	0.2 mi/sec.	0.2 mi/sec.
Helium	0.8 "	0.9 "	Water Vapour	0.4 "	0.5 "
Oxygen	0.3 "	0.3 "	Carbon-Oxide	0.2 "	0.3 "
Nitrogen	0.3 "	0.4 "	Methane	0.4 "	0.5 "
Neon	0.3 "	0.4 "	Ammonia	0.4 "	0.5 "

would be able to retain only heavier gases such as carbon-dioxide and chlorine. Table II lists the molecular speeds for only two temperatures and one must bear in mind the possibility of higher temperatures prevailing. The moon and Mercury are so strongly exposed to solar insolation that their surfaces at noon become very hot, and other planets in their past history may have been very hot so that the terrestrial planets may have lost most or all of their original supply of gases. For example, at the melting point of iron the numbers in columns three and six in table II must be more than doubled.

The Constituents of Planetary Atmospheres

We have seen now how the various lines of evidence indicate that the moon and Mercury are utterly devoid of atmospheres. Lifeless and airless they pursue their orbital motions in the vacuum of space, suffering extremes of temperature as their surfaces are exposed to the untempered blast of solar energy on one hand and the great cold of space on the other. We dismiss them from further study in connection with our subject and inquire now into the composition of the atmospheres found to surround the other planets. In this problem we must rely almost entirely upon the spectroscopic evidence supplemented by a knowledge of molecular spectra. The various planets may be conveniently discussed as follows:

(*a*) *Venus.* The existence of a dense atmosphere is beyond ques-

tion but, until 1932, there was no information as to its composition. In that year Adams and Dunham[1], at Mount Wilson, secured high dispersion spectra of Venus in a search for oxygen and water-vapour. They found no trace of these gases although the venerian components should have been separated from the telluric bands, such was the relative radial velocities of the two objects and the dispersion employed. However, three bands of unknown origin were discovered at wavelengths 7820, 7883, and 8689A in the infra-red part of the spectrum. These bands were tentatively assigned to carbon-dioxide, although they do not appear in the earth's atmospheric spectrum, even under a setting sun. In 1934 Adel and Slipher[2] were able to produce these bands in an absorption tube 45 metres long when carbon-dioxide was pumped into a pressure of 47 atmospheres. In 1937 Adel[3] was able to arrive at a quantitative estimate of the amount of carbon-dioxide above the cloud layer of Venus. It appears that this gas is very extensive indeed, there being at least 2 mile-atmospheres, or 10^{15} tons above the cloudy layer. This is ten thousand times the total amount of this gas present in the earth's atmosphere.

(*b*) *Mars.* The atmosphere of Mars remains one of the major problems in this field. Despite earlier claims to the presence of water-vapour and oxygen, the recent powerful spectroscopic evidence indicates an absence of oxygen and a scarcity of water-vapour. In 1934 Adams and Dunham[4] studied the spectrum of Mars when its radial velocity was such as to separate the martian and telluric components of these two above mentioned gases. Studies of the positions and intensities of the components of the *B* bands of oxygen showed that if any martian oxygen existed it must be less than one-tenth of one per cent. as abundant as that above the surface of the earth. At the same time the water-vapour band was investigated. There was a possible indication of water-vapour in the martian spectrum but the evidence was inconclusive. On the other hand the behaviour of the polar caps of Mars during the martian year is strong presumptive evidence of the presence of water-vapour in the planet's atmosphere and, in this case, is a more sensitive test than the spectroscopic method.

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[1] *P.A.S. Pacif.*, vol. 44, p. 243, 1932.
[2] *Phys. Rev.*, vol. 46, p. 240, 1934.
[3] *Ap. J.*, vol. 85, p. 345, 1937.
[4] *Ap. J.*, vol. 79, p. 308, 1934.

It appears then that Mars possesses a considerable atmosphere, some miles in extent in fact, with little or no oxygen and probably some water-vapour. What the other constituents are we do not know and one must consider the gases listed in the previous section which do not lend themselves to spectroscopic detection. Of these hydrogen and helium are unlikely because of their high velocities and the small gravitational force of the planet. Do the "Martians" then breathe nitrogen as we do oxygen?

(*c*) *The Giant Planets.* The giant planets Jupiter, Saturn, Uranus and Neptune possess atmospheres of considerable extent and density. Their changing streaked surfaces, their high albedos, low mean densities, and heavily banded spectra place the matter beyond doubt. Their great gravitational powers would hold even hydrogen and helium imprisoned at relatively high temperatures. The spectra of these planets show strong absorption bands principally in the red and orange portions of the spectrum and known since the earliest days of spectroscopy applied to the solar system. So strong are these absorptions in the radiations from Uranus and Neptune that they suppress the "natural" yellow colour of sunlight and give rise to the distinctive green hue of these objects. The origin of the bands remained obscure from the time of Huggins in 1875 until 1932 when Wildt[5] showed that a number of the fainter bands in the spectra of Jupiter and Saturn could be explained if they were assumed to be due to the ammonia molecule while others could be attributed to methane. Complete confirmation of this was supplied in 1934 by Adel and Slipher[6] who analysed the bands and actually produced these absorptions in the laboratory in a methane tube with an absorption path 45 metres long under a pressure of 40 atmospheres. A small amount of ammonia absorption is present in the spectra of Jupiter and Saturn but only methane makes itself visible in Uranus and Neptune. Other hydrocarbons, such as acetylene, have been sought but without result. The amount of ammonia above the reflecting layer of Jupiter is calculated as equal to a layer of gas 10 metres thick at normal pressure and temperature; in Saturn the amount is less. The methane constituent corresponds to about one mile-atmosphere on Jupiter and Saturn, much more on Uranus and Neptune. In addition to these noxious gases it is possible and even likely that great amounts of free hydrogen

[5] *Göttingen Veröff*, vol. 2, p. 171, 1932.

[6] *Phys. Rev.*, vol. 46, p. 902, 1934.

and helium exist in the atmospheres of the giant planets. As previously explained, we cannot obtain direct evidence of this possibility.

Quite recently Wildt[7] has advanced a suggestion to explain the many shades of yellow and brown observed in the cloud belts of Jupiter and, to a lesser degree, of Saturn. Solutions of the alkali metals, principally sodium, in ammonia, can be shown to give rise to the various colours to be seen in the cloud belts. This ingenious suggestion meets with few objections and removes one of the unexplained features of the Jovian cloud belts.

Little can be said regarding the atmosphere of the outermost planet Pluto. Spectroscopic evidence is lacking although the colour and albedo place the planet in a class with Mercury and Mars. In size Pluto is like the earth. Pending more complete knowledge of the planet and its probable origin we may conclude that its atmospheric composition partakes more of the nature of the terrestrial than the major planets.

Conspectus of Planetary Atmospheres

The results of our knowledge regarding planetary atmospheres now enable us to draw several conclusions. In this connection one may refer for more details to an inspiring and stimulating article on this subject by Professor H. N. Russell[8] from which much of the material for this lecture has been drawn. A general statement embraces all planets as follows,—"large planets have atmospheres containing hydrogen compounds, medium sized planets have atmospheres containing oxygen compounds, small planets and practically all satellites possess no atmospheres." In tracing the evolution of a planetary atmosphere Russell assumes that the planets were originally formed from solar material, condensing and cooling to their present form. The original or "primitive" atmosphere of a medium sized planet would largely diffuse into space while the body was very hot because of the relatively small value of the velocity of escape. As the molten mass cooled quantities of gas, largely carbon-dioxide, would be freed to form the atmosphere which could not escape because of the lowered surface temperature. The carbon-dioxide would give rise to oxygen through the action of vegetation and the oxygen in turn would be

[7] *M.N.*, vol. 99, p. 616, 1939.
[8] *Science*, vol. 81, p. 1, 1935.

used up by the oxidation of surface rocks. The process would be a very slow one since great quantities of carbon-dioxide would be released over long periods of time. It may be pointed out that while nitrogen makes up a great part of our atmosphere its abundance on the earth is small compared to its cosmical abundance, since it is a very common element in the stellar system. In connection with the above description one is tempted to view Venus as an early stage in this process with its heavy expanse of carbon-dioxide and little or no free oxygen, while Mars, on the other hand, may be approaching the final state. Its carbon-dioxide supply has been exhausted and nearly all its oxygen has united with the surface element, staining its deserts red with iron rust.

The giant planets, because of their great gravitational attractions, would retain their "primitive" atmospheres and begin the cooling process with great quantities of hydrogen, helium, oxygen, carbon and nitrogen. Under the conditions envisaged on these planets two chemical reactions would predominate in the atmospheric gases, the end products of which would be methane, ammonia and water-vapour. The giant planets are now very cold so that the water-vapour is completely frozen out of their atmospheres and in the two outer planets, Uranus and Neptune, the ammonia has also solidified. This picture corresponds satisfactorily to the observed features of the atmospheres of the major planets. In passing, it may be pointed out that if the above views are correct, in that the major planets retained their "primitive" atmospheres, the method of formation of these planets must have been such that large fragments of appreciable density formed the nuclei, for otherwise the original atmospheric constituents must have diffused away from the planet in a short time.

In closing this review, we may note with satisfaction how various branches of scientific endeavour, physics, chemistry, geology and technology have united to shed light upon a perplexing and obscure astronomical problem. Although certain aspects of our subject remain unknown as yet, we may anticipate with confidence a completely satisfactory history and description of the atmospheres of the planets.

Dominion Astrophysical Observatory,
Victoria, B.C.
April, 1940.

ON THE IDENTITY OF THE SUN WITH THE MIDDLE FIRE OF THE PYTHAGOREANS

By E. M. Antoniadi

IN the VIth century B.C., the Greek philosopher Anaximander, of Miletus, in Asia Minor, believed that "the earth is soaring," and that "it moves round the middle of the universe."[1] A few years later, his pupil and friend, Anaximenes, expressed the idea that "the nature of the stars is fiery," and that "they are surrounded by earthly bodies, turning around them invisible."[2] Now, in these passages, which concern the first serious cosmological gropings of the Greeks, we find several flashes of genius:—(1) That the Earth, which appears infinitely ponderous, is yet isolated, unsupported, in space,—a fact which has been rightly considered as constituting the greatest of all astronomical discoveries; (2) that it is not fixed in the middle of the universe; (3) that it revolves, by the translation of its centre, around that middle, obviously occupied by some important heavenly body, the fire, the Sun, as shown later; and (4) that the image of the heliocentric system, thus conceived, was extended to the stars. It is flattering to the science of Anaximenes that the immortal Newton independently asserted, 2,200 years later, that "every star is the centre of a system similar to our own."[3]

A century later, the majority of the disciples of Pythagoras were teaching that our globe, like the planets, turned round "the middle fire." Thus, according to Aristotle, "the Pythagoreans . . . say that there is fire in the middle," and that the earth, being one of the heavenly bodies, moves in a circle around the middle."[4] And "the Pythagoreans," says Simplicius, "considered the earth as a heavenly body, and as an instrument of time."[5] The moving heavenly bodies mentioned by Aristotle are here the planets, of which the Earth is considered as one, because the Stagirite is careful to differentiate the moving, or roving, stars from the fixed ones, which

[1]Theon of Smyrna, *Mathematics useful to the reading of Plato*, ed. Teubner, p. 198.

[2]Stobæus, *Physics*, I, 24.

[3]*Principia*, general scholium.

[4]*The sky*, II, 12.

[5]*Commentary on The sky of Aristotle*, II, 12, 229 *a*.

he calls "attached," in accordance with the custom of the times.[6]

Philolaos the Pythagorean, who flourished in the second half of the Vth century B.C., wrote that "the first thing established, the one, in the middle of the sphere, is called the hearth."[7] According to Stobæus, Philolaos places "in the middle, towards the centre, the fire, which he calls the hearth of the universe, the abode of Jupiter,[8] and the mother of the gods. . . . And around it dance ten divine bodies, the sky, the planets, after which the sun, below which the moon, below which the earth, below which the antichthon, and, after all this, the fire."[9] And he considers "the sun vitreous, receiving the reflection of the fire which is in the universe, and filtering towards us the light and heat, so that there are in some way two suns."[10] Philolaos then places "the ruling principle in the middlest fire."[11] Lastly, according to Eusebius, Philolaos considers "the earth carried in a circle around the fire, in an oblique circle,"[12] the ecliptic, oblique to the equator.

The middle fire was further believed to be "the bulwark, the guard, and the throne of Jupiter,"[13] and "the altar, the junction, and the measure of nature,"[14] as well as "the most important thing in the universe."[15] Hence the Pythagoreans thought that "it became the most precious thing to occupy the most precious place," and that "fire was more precious than earth."[16]

Keppler, Newton, and Laplace, the greatest astronomers since antiquity, rightly felt here a disguised heliocentric system. The penetration of these illustrious men thus enabled them intuitively

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[6]The fact, that the stars are situated at different distances from the Earth was known to the Greeks, as Geminus remarked, towards 80 B.C., that "we must not conceive the stars to be on a unique surface, but admit, that some are more elevated, others less" (*Introduction to the Phenomena of Aratus*, I).

[7]*Fragments*, 4.

[8]In India, the divine Savitri was believed to reside in the Sun; the Sioux and the Commanches thought that the Great Spirit had its abode in that luminary, and so on with other tribes in both Continents.

[9]*Op. cit.*, I, 22.

[10]*Ibid.*, I, 25.

[11]*Ibid.*, I, 21.

[12]*Evangelical preparation*, XV, 58.

[13]Simplicius, *op. cit.*, II, 12, 229 *a*.

[14]Stobæus, *op. cit.*, ed. Meinecke, p. 136.

[15]Aristotle, *op. cit.*, II, 13.

[16]*Ibid.*, II, 13.

to go to the very core of the question, and yet they were at a loss to bring forward historical data in support of their interpretation.

In fact, Philolaos had every reason to veil his theory, as natural philosophers were looked down upon by the people in those times. Thus his master Pythagoras was driven from his native island of Samos by the tyranny of Polycrates; later, he had to withdraw from Crotona and go to Metapontum, in consequence of difficulties encountered with the local authorities owing to his teaching; and his School was at last violently persecuted, when some fifty of his followers had their houses sacked and burned before being killed, perhaps with their leader. At about the same time, Diogenes of Apollonia risked his life on account of the intense hatred inspired by his cosmological speculations; Zeno of Elea was tortured for the same reason by the local tyrant; Anaxagoras was condemned to death, but was saved by Pericles, for having presumed to declare, that the Sun was not a god, but merely an incandescent globe; while Philolaos himself had to fly from Tarentum, or Crotona, and to seek refuge in Lucania, and, later, at Thebes, in Greece.

Another reason of the Pythagoreans for veiling their theories to the public was that they followed the silent and mysterious, enigmatic and emblematic, teaching received by their founder in the various sanctuaries of the Egyptian priests.

A decisive proof of the fact that Keppler, Newton, and Laplace were right in reading between the lines the theory of Philolaos, and that Bœckh, Schiaparelli, Duhem, and Dreyer erred in sticking to the impossible literal sense, is furnished by the identity of the alleged *separate* heavenly body of the Antichthon, or Counter-Earth, with the Moon! Thus Simplicius asserts that "the Pythagoreans called Antichthon the moon";[17] and this is confirmed by Damascius, affirming as well that "the Antichthon designed to them [the Pythagoreans] the moon."[18] Greek astronomy is everywhere misrepresented and belittled, owing to an insufficiency of research, and to a deplorable lack of mastery of the difficult Greek idiom. But the fact that one of the two Pythagorean moons is thus demonstrated fictitious, leads to the strong suspicion that one of their two suns might also have been imaginary; and we are informed by

[17] *Op. cit.*, II, 12, 229 *a*.

[18] *Prolegomena to the IInd book of Aristotle on The sky*, in Brandis, *Scholia in Aristotelem*, vol. IV, pp. 504-505.

Proclus Diadochus that it was an artful device of the Pythagoreans "to consider in double the elements in the sky."[19] The Moon and the Sun must have been doubled for the public, though not for the esoteric teaching, in order to bring up to "the perfect number" ten the bodies revolving around the middle fire.

The comparison and analysis of some old Greek texts found by me at the Bibliothèque Nationale, of Paris, will show that the sun which was considered vitreous and a mere reflection of light and heat, must, exactly like the would-be Antichthon or second imaginary moon, vanish as a nonentity before the middle fire, or real Sun, which the Pythagoreans were careful to locate in the very plane of the ecliptic. The argumentation on this point can be given as follows:—

(1) Simplicius mentions, among others, the Pythagorean doctrine that "in the middle of the universe is the fire;"[20] and the emperor Julian states that "the sun . . . has obtained the middle of the whole sky."[21]

(2) We have seen from Stobæus that the middle fire was "the abode of Jupiter;"[22] and Plutarch asks: "This Jupiter . . . is he not a great and continuous fire?"[23] Then Julian speaks of the god "Jupiter, who is the same [deity] as the Sun."[24] Also, in the celebrated Orphic *Hymn* to the great luminary, the Sun is addressed in the vocative case as "O immortal Jupiter!"[25] An ancient Greek statue bears an inscription, meaning "Jupiter Sun". However, this identification of Jupiter with the Sun was imagined in a remote antiquity, and was abandoned later.

(3) Aristotle has been quoted above as saying that, in the mind of the Pythagoreans, the middle fire was "the most important thing in the universe";[26] and, in the Orphic *Hymn*, the Sun is addressed as "king of the universe."[27] It was natural to consider the Sun as

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[19]*Commentary on the Timæus of Plato*, III, 154 *a*.
[20]*Op. cit.*, ed. Karsten, p. 229.
[21]*To the king Sun*, 134 B.
[22]*Op. cit.*, I, 25.
[23]*On the face appearing in the disk of the moon*, 12.
[24]*Op. cit.*, 149 D.
[25]Verse 13.
[26]*The sky*, II, 13.
[27]Verse 11.

the most important thing in the heavens, since our very lives depend on its beneficient radiation.

(4) It has been stated above that Philolaos placed "the ruling principle in the middlest fire";[28] and Geminus says that "the ruling principle is about the sun";[29] while, according to Diogenes Laertes, "Cleanthes [considered] the ruling principle of the universe . . . [to be] the sun."[30]

(5) We found Eusebius stating that Philolaos thought "the earth carried in a circle around the fire, in an oblique circle",[31] the ecliptic; and, according to Plutarch, Aristarchus the Samian supposes, that the Earth turns round the sun, and "in an oblique circle",[32] the ecliptic.

(6) Lastly, an infinitely precious passage of Simplicius informs us that "those who partook more authentically" in the theories of the Pythagoreans say that the latter "were really calling fire in the middle, the creative power, which vivifies from the middle all the earth, and which warms its cooled part."[33] Here I had to find ancient Greek texts glorifying: (*a*) the creative power of the Sun; (*b*) its vivifying power; and (*c*) its warming power. These texts are the following:—

(*a*) Theophrastus speaks of "the sun, who creates all these things";[34] the emperor Julian admires "the creative power coming from the sun",[35] and Proclus Diadochus "the creative powers of the sun."[36]

(*b*) Orpheus celebrates the Sun as "life-bringer";[37] and Theophrastus considers "the birth of living beings, and plants, which are begotten by the sun."[38]

(*c*) Aristotle mentions "the heat coming from the sun, which

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[28]Stobæus, *op. cit.*, I, 21.
[29]*Op. cit.*, XVII, 45.
[30]*Zeno of Cittium*, 70.
[31]*Op. cit.*, XV, 58.
[32]*Op. cit.*, 6.
[33]*Op. cit.*, II, 12, 229 *a*.
[34]*Of fire*, 5.
[35]*Op. cit.*, 140 B.
[36]*Commentary on The republic of Plato*, 148 v.
[37]*Hymn to the sun*, verse 12.
[38]*Metaphysics*, 15.

has a principle of life";[39] and it is, of course, useless to say, that it is *only* the Sun that warms the Earth.

We have thus seen, that the middle fire was conceived to be in the middle of the universe; that it was identified with the abode of Jupiter; that it was the most important thing in the universe; that it was the ruling principle of the universe; that it lay in the very plane of the ecliptic; that it had a creative and a vivifying power; and that it warmed the Earth. And as all these properties, or attributes, were, according to the unexceptionable Greek texts above given, characteristic of the Sun, there can be no doubt whatever that the Middle Fire of the Pythagorean School was the Sun; and that, consequently, five centuries B.C., the idea of the heliocentric system had already dawned in the mind of the Greek philosophers.[40]

[39]*On the generation of animals*, II, 3, 736.

[40]The ancient texts, as they came down to us, represent Philolaos placing Mercury and Venus beyond the Earth's orbit. This could scarcely be true. Now, if we add to the above notions the fact that Aristarchus spoke of the rotation and revolution of the Earth round the Sun; that Seleucus asserted these two movements; that Heraclides Ponticus made Venus, and Theon of Smyrna Mercury also, turn round the Sun; that the emperor Julian affirmed the dance of all the planets round the Sun; that Plato conceived the rotation of all the heavenly bodies; and that Aristarchus explained the apparent lack of parallax of the stars by their infinite distance; we find that Greek genius has discovered a complete heliocentric system, more accurate than that bearing the name of Copernicus, and this with an anteriority of from twelve to twenty-one centuries.

BY THE LIGHT OF THE SUN*

By H. Boyd Brydon

THE title of this talk, "By the Light of the Sun," may sound peculiarly inappropriate for Hallowe'en when witches ride the air and spectres are wont to walk. But I am not so sure of that for if we do not speak of spectres we shall have much to say about spectra and neither spectres nor spectra can be seen without the basic subject of these talks, Light.

Last Tuesday evening we discussed the apparent size, position and shape of the newly risen full moon. Although we found no satisfactory explanation for her exaggerated size, like beauty it seems to be in the eyes of the beholder, we learned that refraction, the bending of the rays of her light as they come to us through the air not only cause the moon to appear above the horizon when actually she is below it but also cause the curious deformation of her disc into the delectable shape of a Christmas plum pudding. Two experiments and a sort of working model were suggested to illustrate these effects of refraction and I hope you did the experiments and worked the model.

The question of what light is did not arise; in fact I took care that it should not, but tonight our subject is the *colour* of light and some workable answer is unavoidable.

The most we can say is that light is a form of energy. What energy is, we do not know. One writer has said "energy is a series of pushes or pulls or whirlpools in nothingness." What that means I leave you to guess. As a tissue of contradictions it surpasses the French gentleman's celebrated description of a hot toddy: "You put whiskey in to make it strong, water in to make it weak, lemon in to make it sour, sugar in to make it sweet and you say 'Here's to you' and drink it yourself."

No, when it comes face to face with fundamentals; space, time, energy, life, science can describe but cannot explain. The manipulation of enigmatic mathematical formulae serves only to emphasize our ignorance. "It's so but we don't know why it's so." Even the oft quoted Sir James Jeans has to admit "a growing conviction that

*A radio talk over Station CFCT, Victoria, B.C., October 31, 1939.

the ultimate realities of the universe are at present quite beyond the reach of science and may be and probably are, forever beyond the comprehension of the human mind."[1]

But although we know not what energy is, we do know that the forms in which it appears, whether it be that mystery received by our radios or the sound energy from which it comes and into which it is transformed, or the energy of heat or of the many forms we know as rays, X-rays, gamma rays, cosmic rays and the rest, all behave as waves. All are parts of the one great gamut of vibration we call energy. The name is merely a convenience; it is not an explanation. It is useless for us to speculate about the stuff in which the waves occur or why. We can only say that these waves *are* energy, as water waves are water and let it go at that.

Waves can be of different lengths. There are the long and short radio waves from which we select the one which carries our favourite programme; long and short sound waves which give us the sensation of low tones and high tones and there are long and short light waves which give us the sensation of different coloured lights.

Suppose you heard all the notes of a piano struck at once. You would undoubtedly call the resulting sound a noise. Sunlight, or white light as we shall call it, is just such a noise in the world of light. When the piano notes are struck in order, starting let us say with the long sound waves of the deep bass and reaching the short waves of the upper treble we hear the separate tones that sounding together made the noise. Similarly, the jangle of long waves and short waves and in between waves that is white light can be separated into the orderly band of coloured light called a spectrum. At one end of the band are the long waves of red light, then, through a gradation far more delicate and precise than the tones of a piano come the shorter orange, green, blue and finally the very short violet waves, each shade of colour being produced by waves of one length only.

We are all familiar with those little triangular rods of glass called "lustres" which were so popular at one time for ornamenting chandeliers. Candlebra decorated with them are to be seen in most antique shops where broken pieces of lustres can be had for the asking. Pick out a nicely polished piece. The uncut part will serve as a prism.

[1]The Universe Around Us.

Let sunlight passing through your prism fall on a white surface or, to see a spectrum which, though very small, will have brighter, "purer" colours, stick a bright new pin into a dark background in bright sunshine and from a distance of two or three feet look at it through your prism. You may have some difficulty in finding the tiny spectrum because the light reflected by the pin will be greatly bent by refraction in passing through the prism. You will have to look round the corner as it were. But when you do find it you will see it glowing with all the colours of the rainbow. That statement is literally true by the way because rain drops do exactly the same thing to white light as a prism does. Both separate it into its component parts, showing that white light actually is a mixture of lights of all colours.

There is nothing new in this. You have heard the same thing over and over again. But did you ever stop to wonder why a piece of flat transparent glass such as window glass lets white light pass through it unaltered while a wedge shaped piece separates it into light of all colours? What a tremendously different result simply because a piece of clear glass is wedge shaped instead of flat. What is the reason? Let us see.

Last week the average speed of light in glass was stated to be about 120,000 miles a second and in air about 186,000 miles. These figures are for white light. The actual speed, however, depends to some extent upon the colour of the light or, to speak more precisely, upon its wave length. When this variation of speed with colour is investigated it is found that there is less difference between the speeds of red light in glass or water for instance and in air than there is between the speeds of violet light in glass or water and in air.

We saw last week, you remember, that when light passes obliquely from one substance into another the resulting change or difference in speed causes it to be refracted; the greater the difference, the greater the degree of refraction. It follows from this that when lights of different colours pass obliquely from one substance into another their different relative speeds cause them to take slightly different directions; their paths diverge. The long wave red light is refracted the least and the short wave violet light the most. That is why red,

being refracted least by the rain drops is on the outside of the principal rainbow and on the inside of the secondary bow if there is one.

With flat glass, these differences in the degree of refraction as the light passes from the air into the glass are cancelled out by the reverse bending as the light passes out of the glass into the air again and the light continues on in its original direction none the worse for its experience. But when the glass surfaces are inclined to one another, these opposite refractions cannot cancel out and the diverging light waves leave the glass as a band of coloured light.

All waves behave very much alike. Whether they are radio waves or sound waves, light waves or water waves they can all be reflected and refracted and broken up and scattered by obstacles. Let us then for convenience look at some water waves. Watch them on the sea when there is a fresh breeze blowing. Pick out a place where the kelp is floating and watch what happens. A big wave comes along and sweeps through the kelp unhindered. But the little waves and the ripples on the sides of the big waves fare differently. They are stopped, broken up, scattered. This happens to all kinds of waves when they meet an obstacle. If the obstacle is not too big they pass unaffected. If it is, they are scattered.

This observation leads us to the explanation of why the sun is red and the sky blue.

As it reaches the earth, sunlight has to run the gauntlet of three important obstacles. The first is air. Air is composed of the molecules of certain gases, chiefly nitrogen and oxygen. The word molecule, means "a little mass."

These molecules are exceedingly small but they are large enough to scatter blue light waves which are exceedingly small also. The red waves, being longer, are less scattered. In the process the molecules become flooded with the blue light and reflect it away again in all directions. Some of it reaches our eyes and makes the sky look blue.

The droplets of water vapour which form the clouds are the biggest obstacle. They are so large that they scatter all light waves and consequently the light they reflect is white. That is why diffused daylight is white and why all clouds have a silver lining.

Both these effects of light scattering can be seen in the smoke of

a cigarette. The tiny particles curling upwards in still air from the burning end are only large enough to scatter the small blue waves. In turn they reflect the blue light and we say the smoke is blue. When the smoke is drawn into the mouth, however, the particles absorb moisture and become so much larger that like the clouds in the sky they reflect all or nearly all the light and we say that smoke is white.

The third obstacle, dust floating in the air, is chiefly responsible for the red colour of the setting sun. The light of the sun is always the same colour, white; but at sunset as it comes to us nearly horizontally through a great thickness of dense, dust laden air, not only the blue light but a great deal of the green also is scattered and only the orange and red light wins through to turn the pearly whiteness of Mt. Baker to an even more lovely pink and we see the sun chiefly by its red light.

When the smoke from burning forests is added to the floating dust as all too frequently happens the scattering of all but the very red rays is practically complete and the sun shines as a crimson ball in the murky sky.

Now do you still need a pointer as to why the rising moon is red? Very well; she shines only by reflecting the light that reaches her from the sun and about the time of full moon the sun is setting as the moon is rising.

We have likened the colours of light waves to the tones of piano notes. But there is a vast difference between them also. The same piano notes are used in countless tunes. Each individual light wave, however, is the exclusive property of but one only of the ninety-two elementary substances recognized by the chemists; is a part of its private signal so to speak; of its distinctive spectrum. Whether that spectrum contains lights of two or two thousand separate and distinct wave lengths, light of exactly those wave lengths appears in no other spectrum.

The discovery of this fact ranks with the very greatest in all physical science. From it has come perhaps the most powerful aid we have in our research into the nature of things. It gives us knowledge of the composition of the stars, their temperatures, conditions, motions and their sizes and distances and even demonstrates their existence where photography is powerless to reveal them. It has proved the

sun to be but one among billions of stars all whirling in a great spiral cloud whose direction and distance it has shown us but which we cannot see, such a spiral as we can discover faintly even with the naked eye in the far off constellation of Andromeda.

It has led us also to knowledge of the infinitely small, to the constitution of the atom itself; has shown us that it is a solar system of whirling electrons[2] and that far from being solid, matter is tenuous as the stuff of dreams. And these are but the beginnings of its teachings.

Would you like to see some of these spectra? Then take your prism down the street and examine by its aid the glowing tubes of the advertising signs. Stand across the street from the sign and hold the prism with its long edge parallel to a straight piece of the tube. Red neon tubes become a narrow triple, red, orange, yellow; blue mercury tubes a wider triple, faint yellow, intense green and deep blue; green tubes a double, yellow and green. Yellow sodium tubes remain a single colour yellow. If the colours overlap stand farther away so that the narrow source of light looks narrower still and the spectrum is "pure," as pure as you can fairly expect from a merely ornamental wedge of glass.[3] As the patent medicine advertisements say: "Try it and be convinced."

2390 Oak Bay Ave.,
Victoria, B.C.

[2]Cf. Eddington: New Pathways In Science, 1935 ed., p. 29.

[3]This paragraph is adapted by his kind permission from that most readable and understandable book "Physics" by W. H. White, published by Clay and Sons, Blackfriars House, London E.C., England.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Notes from the Dominion Astrophysical Observatory

Continuing the record from the November, 1939, issue of the Journal, we have the following "observing statistics":

Month	Nights	Hours	21-year average Nights	21-year average Hours
1939, October	12	96.6	17	129.2
November	7	53.3	16	86.6
December	10	50.0	10	66.0
1940, January	12	82.4	10	63.6
February	10	51.2	13	90.0
March	14	97.8	14	97.8

Thus the observing weather was about twenty per cent. below average for these particular months. Nevertheless, some good spectrograms were obtained, among them being some of the new star in Monoceros. These showed that it had passed into the nebular stage exhibiting the typical bands of hydrogen, oxygen and nitrogen.

As usual, members of the staff have been called upon to give numerous addresses upon astronomy and allied subjects to local organizations. In addition, Dr. Beals lectured before Vancouver audiences on his trip last summer to the Astrophysical Congress in Paris, while Dr. Petrie goes over there in April to speak on "The Atmospheres of the Planets".

Congratulations are due to two of the members of the staff. Mr. K. O. Wright completed his research on "The Line Intensities of Four Solar-Type Stars" and submitted the thesis to the University of Michigan as a partial requirement for the degree of Doctor of Philosophy. It was accepted and in March he went East to complete the formalities by taking the oral examination in which he was successful.

Congratulations are also due to Dr. R. M. Petrie on his election as a Fellow of the Royal Society of Canada.

W. E. H.

For Members Visiting Toronto

Members from other centres visiting Toronto at any time, and especially during the summer months, are invited to telephone the General Secretary, Mr. E. J. A. Kennedy, RAndolph 6100, or the Assistant Secretary, Miss E. M. Budd, RAndolph 7186, for appointments to visit the offices of the Society, or for any other information desired. The Council of the Society is anxious that the facilities of the Toronto headquarters be as available as possible to all members.

A War-Time "Solar Eclipse"

Mr. F. J. Sellers, Director of the Solar Section of the British Astronomical Association, London, England, records the following interesting observation in the January, 1940, number of the Journal of the B.A.A.:

On Friday, December 22, at 10.45, while I was recording details of the solar disc with the spectrohelioscope, I suddenly became aware that the sun was being occulted by a sharp opaque curve, apparently part of a disc of equal diameter to that of the sun. For a moment I was nonplussed. There was an unpredicted solar eclipse and the moon eleven days old!

At first I thought that something in the observatory, though I could not imagine what, had interposed itself in the line of collimation of the instrument. I quickly realised, however, that the occulting limb was so nearly in focus with the solar disc itself that this could not very well be.

Then it dawned upon me that the rounded nose or fin of a barrage balloon was slowly encroaching between the sun and my coelostat. The eclipse was explained and was soon over.

The Jubilee of the British Astronomical Association

Dr. W. E. Harper has called attention to the fact that the British Astronomical Association was founded in 1890, the same year in which our own Society was incorporated. The following extract from the constitution of the B.A.A. may be interesting to our members, who will note the similarity in aims, publications and methods between this association and our Society.

The British Astronomical Association was founded in 1890 and now has over 900 members. Its leading features are:

Membership.—Open to all persons interested in astronomy.

Objects.—(1) The association of observers, especially the possessors of

small telescopes, for mutual help, and their organization in the work of astronomical observation.

(2) The circulation of current astronomical information.

(3) The encouragement of a popular interest in astronomy.

Methods.—(1) The arrangement of Members, for the work of observation, in Sections, under experienced Directors.

(2) The publication of a *Journal, Handbook* and *Memoirs.*

(3) The formation of Branches.

(4) The holding of Meetings in London, and at the seats of the Branches.

(5) The formation of a library and of collections of astronomical instruments and lantern slides, for loan to Members.

(6) The affiliation of Schools and Societies at the same fee and with the same privileges as Members.

Annual Subscription.—£1 1s. *Entrance Fee.*—5s.

Meetings are held on the last Wednesday in each month from October to June inclusive, at Sion College, Victoria Embankment, London, E.C. 4, beginning at 3 p.m.

The principal publications are the *Journal,* the *Handbook* and the *Memoirs,* all of which are supplied free to Members.

The *Journal* is published ten times a year; it contains Reports of the Meetings, Reports of the Branches and Sections, papers by Members and notes on current astronomy.

The *Handbook* is published annually and contains mainly information of an ephemeral nature, supplementary to that in the *Nautical Almanac.*

The *Memoirs,* published at irregular intervals, contain the longer Reports of the Observing Sections.

The *Circulars,* giving immediate information of the discovery of novae, comets, etc., are issued for a special subscription of 2s. 6d. per annum.

The Library, which now contains about 3000 volumes covering all branches of astronomy, is open before and after each Meeting for the issue and return of books. On all other Wednesdays it is open as a reading-room, as well as for the usual book exchanges, from 2 to 6 p.m., but books may also be obtained by written application to the Hon. Librarian, British Astronomical Association, Sion College, Victoria Embankment, London, E.C. 4.

The Toronto Meeting of the A.A.V.S.O.

In the March number of this Journal we published the programme of the Spring Meeting of the American Association of variable Star Observers, to be held in Toronto at the invitation of the Toronto Centre of the R.A.S.C., on May 31 and June 1.

Arrangements have now been completed to have as the speaker at the Friday night meeting, Professor John Satterly, D.Sc., F.R.S.C.,

of the Department of Physics, University of Toronto, who will lecture on "Experiments with Liquid Air." Thanks to Dr. Satterly's dramatic manner of presenting scientific lectures, and to the excellent facilities of the University's crynogenic plant, an instructive and enjoyable evening is assured.

At the Saturday night banquet in the Great Hall at Hart House, after-dinner speakers will include Professor Harlow Shapley, of Harvard, Mr. Leon Campbell, the Recorder of the A.A.V.S.O., and Professor Chant.

Members are reminded that reservations should be sent to Mr. E. J. A. Kennedy, 198 College Street, Toronto, or Dr. Helen S. Hogg, David Dunlap Observatory, Richmond Hill.

F.S.H.

MEETINGS OF THE SOCIETY

AT VANCOUVER

December 12, 1939.—The sixty-seventh regular meeting, the ninth *annual* meeting, of the Vancouver Centre was held at 8.15 p.m. in the Science Building of the University of British Columbia.

The secretary read his report of the activities of the Vancouver Centre during the year 1939.

The treasurer read his report of the year's receipts and disbursements. The financial position of the Society continues to be favourable. The auditors then audited the treasurer's report.

The executive for 1940 was chosen. Mr. Jorgensen moved and Mr. Acton seconded the motion that the officers proposed by the retiring executive be elected unanimously. The list of officers appears elsewhere in the JOURNAL.

Following the election of these officers by the members, the president called on the speaker of the evening, Dr. R. Jeppesen, of the Department of Physics, who spoke on the subject "Diffraction Gratings."

By way of introduction the speaker pointed out the fact that a very considerable portion of all observational data upon the stars consists of spectrograms from which wave lengths and intensities of spectral lines are obtained. While the diffraction grating has not been of so wide use in stellar spectroscopy as have prism instruments, the laboratory studies of spectra are of no less importance to astrophysics than to physics proper.

A short discussion of the action of a grating in diffracting light and forming a spectrum was given, and from this point of view the requirements of enormous precision and delicacy of construction of the grating were outlined. In order to indicate the magnitude of the problem confronting the maker of a grating, the methods of Fraunhofer, who was first to make and use one of these instruments, were described. Fraunhofer's gratings consisted of a number of fine equally-spaced parallel wires, the spacing being about 0.005 cm. for his finer gratings. Then the contributions of F. A. Nobert, of Pomerania, of L. M. Rutherfurd of New York, and especially of Prof. Henry A. Rowland of the John Hopkins University were discussed. Still other achievements by Sir Thomas Lyle and Prof. A. A. Michelson received notice. Next Professor R. W. Woods' important contribution of a few years ago, that of ruling gratings upon a chrome aluminum surface evaporated upon a glass blank was described. Finally a few of the methods for using gratings in both stellar and terrestrial spectroscopy received attention.

A laboratory demonstration in which the famous Balmer series spectrum of atomic hydrogen could be observed by means of gratings had been arranged.

The audience observed this spectrum using a grating of the Fraunhofer type as well as by use of modern grating replicas having as many as 20,000 lines per inch.

Dr. Jeppesen's lecture and demonstrations were much appreciated by the members of the Society, many of whom stayed after the meeting to become more familiar with diffraction phenomena by personal experimentation.

A. M. CROOKER, *Secretary.*

AT VICTORIA

November 22, 1939.—A regular meeting of the Victoria Centre of the Royal Astronomical Society of Canada was held in the Y.W.C.A. parlours, Wednesday, November 22, at 8.00 p.m. The President, Mr. R. Peters, was in the chair. It was announced that the second annual dinner would be held December 13 at 6.30 p.m., and that Dr. Plaskett would be the main speaker. Mr. Peters outlined current astronomical phenomena of interest to amateur observers.

The speaker of the evening was Dr. C. S. Beals, who had chosen as his topic "An Astronomical Trip to Paris." Dr. Beals gave a lucid account of features of astronomical interest occurring during his recent trip to France. Paris, he said, has been for centuries a centre of learning and has contributed much to astronomy, but recently there has been a tremendously increased interest in observational and astrophysical astronomy.

The subject of the conference which Dr. Beals attended, "Novae and White Dwarfs," had been chosen to decide whether the white dwarf theory of the origin of novae was tenable in the light of modern physics and astronomy. The number of novae recorded during the past fifty years has been great enough to indicate that each star may have a novae outburst at some time during its life, although the great number of novae is more probably due to intermittent outbursts of some few stars.

The speaker gave a full account of the conference itself and outlined several of the scientific results. The main personalities of the conference were made vivid by slides and verbal descriptions. Other slides showed points of interest in Paris, in Holland, in England, at the Greenwich Observatory and Oxford and Cambridge.

P. RIDDLE, *Recorder.*

December 13, 1939.—The meeting took the form of an informal dinner, held at the Y.W.C.A.. The well-attended function, some 60 persons being present, commenced at 6.45 p.m. As the dinner concluded, those present were favoured, first with two fine bass solos by Mr. James Petrie, and then two enjoyable numbers by an instrumental trio composed of Mr. and Mrs. Darimont and Mr. Gordon Shaw. The president then presented the names of eight applicants for membership in the Centre, and the motion of Dr. Petrie that the secretary be empowered to cast an unanimous ballet for their election was passed. After the minutes of the previous annual meeting were duly read and adopted, the treasurer's report for the year 1939 was read and adopted. The secretary then

presented his annual report, which in turn, was adopted by the meeting. Before a brief recess the meeting enjoyed two excellent piano solos by Mrs. Beals.

After the recess the results of the election for officers were read by the president.

After a considerable banging and commotion, there entered the room a man identifying himself as Professor Whoosis, the astrologer. He proceeded to enlighten the meeting with various predictions for 1940. This act by Mr. Shaw was excellently done and was very amusing and very well received. There ensued a brief report by Dr. J. A. Pearce on plans of the General Executive of the Society for celebrating the Society's semi-centennial in 1940.

The main event of the evening, an address by Dr. J. S. Plaskett on the "History of the Founding of the Dominion Astrophysical Observatory at Victoria," followed. Dr. Plaskett explained, in a most interesting fashion, the various necessary preliminaries, both scientific and political, to the establishment of the observatory. He stressed the contributions of Dr. W. F. King, then Chief Astronomer for Canada, and of various legislators from British Columbia. A vote of thanks for his excellent talk was proposed to Dr. Plaskett by Mr. H. Boyd Brydon.

After endorsing the sending of a message of felicitation to Dr. W. E. Harper, who has been ill for some time, and approving of the conveying by wireless to Mr. A. I. Deacon at Coppermine, N.W.T., of the Society's greetings, the meeting adjourned.

ANDREW MCKELLAR, *Secretary-Treasurer.*

AT TORONTO

February 6, 1940.—The regular meeting of the Royal Astronomical Society of Canada, Toronto Centre, was held in the McLennan Laboratory, University of Toronto, on 1940 February 6. Mr. S. C. Brown was in the chair.

The speaker of the evening was Mr. James R. Gibbs, M.R.A.S., who spoke on "A Race to the South Pole." This was a very enjoyable historical lecture of the expeditions of Scott and of Amundsen to the south pole in 1910-12. The lecture was copiously illustrated by slides of Amundsen and also of Shackleton, whose expedition of 1908-09 did not reach the south pole, but reached the latitude of 88° 23'S. The route discovered by Shackleton for reaching the great plateau was followed by Scott in 1910. Scott's party, while carrying out a survey, were amazed to find the Fram, carrying a party under the Norwegian Amundsen.

Amundsen, after successfully laying depots, set out for the pole 1911 October 20, accompanied by four companions on ski and 52 dogs. They found a new route up to the polar plateau, and reached the pole on December 14. The return journey took only 38 days. No attempt was made at any serious scientific work. Meanwhile Scott's party started for the pole 1911 October 24. After many mishaps with motor-sledges, ponies and dogs, Scott and four others reached the pole 1912 January 18, having hauled the sledge themselves. They were disappointed to find that the other party had reached the pole first. Due

to extreme weather conditions and lack of a sufficient supply of food the party was unable to reach their base, and ended disastrously. There is very little life in the south polar regions. A few species of seals, whales, skua gulls and penguins are about the only inhabitants. The slides of the penguins were particularly delightful. Shackleton found coal about 300 miles from the south pole. Two fresh water lakes were found. The life in this water could not be killed by repeated boilings and freezings. The lecture was of particular interest in view of the present expedition to the Antarctic by Commander Byrd.

Dr. Hogg's subject for the evening was "Proper Motions and the Sun's Way." The apparent motions previously considered by Dr. Hogg have been shown to be due to the motion of the earth. Halley, in 1718, found, by comparison of contemporaneous positions of the stars with those published by Ptolemy about 150 A.D., that the positions of various stars differed. This difference Halley attributed to the motions of the stars themselves.

The sun is a star, and it would be expected to have a proper motion. If the sun is moving and the stars are fixed, the stars in the region of the sky toward which the sun is moving will appear to be spreading out; those abeam will drift back and close in towards the antapex. The solar motion was first detected by Sir William Herschel in 1783 from some 7 stars. The apex at present is taken as α 18^h 00^m, δ +30°, and confirms Herschel's rough estimate. Unless the distances of the stars are known the actual speed of the motion cannot be determined from proper motions. The most accurate knowledge comes from a consideration of radial velocities.

February 20, 1940.—The regular meeting of the Royal Astronomical Society of Canada, Toronto Centre, was held in the McLennan Laboratory, University of Toronto, on 1940 February 20. Mr. S. C. Brown presided.

The following were elected to membership in the Toronto Centre:

Mr. R. G. Colgrove, Pickering College, Newmarket, Ontario.
Mr. H. B. Hall, 15 Robinwood Road, Forest Hill, Toronto.
Mr. Geo. B. Munco, 1 St. Ives Avenue, Toronto.
Mr. A. G. Plumptre, Hydro-Electric Power Co. of Ontario, Toronto.
Mr. R. D. Ratz, 187 Claremont Avenue, Kitchener, Ontario.

The first speaker was Miss R. J. Northcott of the David Dunlap Observatory, who spoke briefly on the subject "Planets to West of Us." We became planet-conscious during 1939 due to the near approach of Mars to the earth on July 27. The planets in the evening sky since the last half of November are Venus, Mars, Jupiter, Saturn and Uranus. By the end of February Mercury will have reached a maximum elongation, and will be well placed for observation. The planets are ranged in the order—Mercury, Jupiter, Venus, Saturn, Mars and Uranus. They will all be about equally spaced on February 28 and are all past the meridian in the western sky. A diagram of the aspect of the western sky one-half hour after sunset on February 28 is given in the current *Handbook* on page 25. It will be noted that of the major planets only Neptune and Pluto are in another part of the sky, and even these two will be above the horizon before Mercury sets. This close grouping of the planets is very

unusual and is not expected to recur for some hundreds of years. A brief description was given of the appearance in a small telescope of the planets in the western sky.

The second speaker was Mr. Duncalfe who described some of the properties of the five regular solids, tetrahedron, hexahedron, cotahedron, duodecahedron and eisasahedron. Mr. Duncalfe had made models of these solids out of wood, and these were on exhibition. The workmanship of these models was much admired. Mr. Duncalfe pointed out that there was an atlas by Proctor based on the duodecahedron. Twelve circular maps, slightly overlapping, presented the positions of the stars with very little distortion. Dr. Heard mentioned that Kepler, before deducing the laws of motions of the planets, had tried to find a relation between the regular solids and the number and distances of the planets from the sun.

Mr. Brown then invited the members to answer the questions suggested at the previous meeting. These answers to the questions were elaborated upon by the chairman.

Dr. Hogg considered a new type of motion in his lecture, "Radial Velocities and Solar Motion." Hitherto motions visible to the naked eye, assisted perhaps by a telescope, or motions on the celestial sphere, had been considered. He traced the historical development of radial velocity measures.

The complete motion of a star is a combination of the motion across the line of sight with the radial velocity. In order to get the space velocity the distance of the star must be known, so that the proper motion can be translated into km. per sec. across the line of sight.

By averaging the radial velocities for a large number of stars, the direction and velocity of the sun's motion can be determined. We conclude that the sun is moving towards R.A. 270°, Dec. 30° at a speed of 19.6 km. per sec.

March 5, 1940.—The regular meeting of the Royal Astronomical Society of Canada, Toronto Centre, was held on 1940 March 5, in the McLennan Laboratory, University of Toronto. The chairman, Mr. S. C. Brown, presided.

The speaker of the evening, Professor J. O. Wilhelm, of the Department of Physics, University of Toronto, gave a very interesting lecture, entitled "What Time Is It?" Mr. Wilhelm enumerated ten astronomical kinds of time and pointed out that physicists are mainly interested in time as one of their fundamental units, time, mass and length.

The ancients were more interested in the seasonal times in the unit of time between full moons. These served until some 3,000 years ago, when people began to become interested in more accurate divisions of time. There is some difference in opinion as to which form of clock was the earlier, the sundial or the water clock. Prof. Wilhelm showed a very interesting group of slides of early sundials and clocks. A very early Chinese sundial, at present in the Royal Ontario Museum, was shown. This sundial was studied by Dr. Millman, and a model of the dial, as reconstructed by Dr. Millman, was exhibited. Other sundials, some made by our members, were also shown.

The early water clocks consisted essentially of a bowl with markings on the inside, and a small orifice at the bottom through which the water flowed. More elaborate ones moved a hand on a dial.

The flame clock, in which oil burns at a uniform rate, and the hour-glass are two other forms of time-keeper. Of particular interest were the slides of cathedral clocks. These are most elaborate, and often give the movable church feasts over a long period of time. Figures, known as "Jacks", struck the hours.

The early clocks had gears made of wood and were run by weights. In the 16th and 17th centuries the clocks had only one hand. A balance device was used before the discovery of the pendulum by Galileo about 1600. Many improvements have been made in clocks until now the best that can be expected from an astronomical clock is a variation of 0.001 seconds per hour. The physicists have found a much better time-keeper in the quartz crystal, which if kept at a fairly constant temperature, will vary no more than 0.0001 seconds per hour. The earth is the best time-keeper we have, varying about 0.000025 seconds per hour. Mr. Wilhelm concluded by saying that physicists may yet find a better time-keeper than the quartz crystal.

Dr. Millman showed slides that he had taken of the group of planets in the western sky. He drew the attention of the members to the possibility of mis-identifying the "ghost" of a fairly bright object, such as Venus, as a new comet or a nebula.

Dr. Hogg spoke on "Multiple Stars and Clusters."

Mr. Brown announced the subject for the next meeting before the present meeting was adjourned.

April 2, 1940.—The regular meeting of the Royal Astronomical Society of Canada, Toronto Centre, was held in the McLennan Laboratory, University of Toronto, on 1940 April 2. Mr. S. C. Brown presided.

The speaker of the evening was Miss Edna M. Fuller, B.L.S., of the David Dunlap Observatory. Her subject, one of great interest to the members, was "Astronomical Reading for the Amateur".

Until fairly recently the subject of astronomy has been rather neglected in the school curriculum. Thus people became interested in the subject through different channels. Some were taught the constellations by their parents and so have always been interested in the subject. Others may have "had a friend", as often happens among amateurs. Many become permanently interested in astronomy through their reading. This is particularly true of adults. Popular periodicals serve to interest readers who may have a limited time for reading. Among the non-technical periodicals discussed, chosen as representative of the types of periodicals published were *The Sky, The Telescope, The Monthly Evening Sky Map, Popular Astronomy* and our own JOURNAL.

The books discussed were selected from those published during the years 1935-1940, and divided into sections Popular Books, Semi-popular Books, Textbooks and Observer's Aids. In the Popular Book section books were chosen to represent the descriptive and historical aspects of astronomy. As

examples of the descriptive books "Through the Telescope" by E. A. Fath and "Stars and Telescopes" by James Stokley may be given, and "A Hundred Years of Astronomy" by R. L. Waterfield as an example of the historical books. It was brought to the attention of the members that the revised edition of "Our Wonderful Universe" by C. A. Chant is now in press and will be available shortly. Other books of popular appeal which were included in this section were "Stars and Men" by S. A. Ionides and Margaret L. Ionides and "The Glass Giant of Palomar" by David O. Woodbury. The Semi-popular Books in general dealt with one aspect of astronomy, such as, "The Sun" by Giorgio Abetti. A number of textbooks were discussed, the most recent one being "Astronomy" by W. T. Skilling and R. S. Richardson.

In conclusion, books of practical value to telescope makers and observers were considered. In this class the books "Amateur Telescope Making" edited by A. G. Ingalls and Norton's Star Atlas were mentioned. It was stated that of course all members would realize that the *Observer's Handbook* is indispensable to the observer.

Dr. Hogg's subject was "The Rotation of the Galaxy". The cross-section of our galaxy shows a very decided flattening that strongly suggests rotation, and the similarity of our galaxy to the extra-galactic nebulae, which are known to be rotating, adds weight to this suggestion.

The possibility of detecting this motion depends on the distribution of the stars. Due to a high concentration at the centre of the system the stars near the centre of the galaxy move more rapidly than those farther out. This would be observed by the stars between us and the centre overtaking us, while those in the opposite direction should drop back. Stars at right angles to the direction to the centre are at about the same distance from the centre as is our sun, so that they are moving in the same direction and at about the same speed as the sun. This was actually found by Oort in 1927 from a statistical study of the motions of the stars of our galaxy. The relative motions due to galactic rotation are shown by both radial velocities and proper motions. The effects become more marked for objects at greater distances so that radial velocities of early type stars, of cepheid variables, of planetary nebulae and of the distant globular clusters have been of particular value in getting numerical results.

It is found that the galaxy is rotating about a centre in the direction of the bright star cloud in Sagittarius, R.A. 17h 24m, Dec. 30°S. The distance to the centre is 32,000 light years; the diameter of the galaxy is 100,000 light years; the mass is 200 thousand million times that of the sun. The velocity of the sun about the centre is 162 miles per second, but it takes 220 million years to make one revolution.

A brief discussion followed Dr. Hogg's lecture. Dr. Millman reminded the members of the special meeting in conjunction with the A.A.V.S.O. on May 31 and June 1, and invited those who could to attend the meetings and the dinner. The meeting then adjourned to examine the books in the rather elaborate display arranged by Miss Fuller.

RUTH J. NORTHCOTT, *Recorder*.

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1890-1940

This year marks the completion of the first fifty years of the corporate existence of our Society. The Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal, P.Q.; Ottawa, Toronto, Hamilton and London, Ont.; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as about 700 members of these Canadian Centres, there are over 200 members not attached to any Centre, mostly resident in other nations, while some 300 additional institutions or persons are on the regular mailing list for our publications.

The Society publishes a monthly JOURNAL containing about 500 pages and a yearly OBSERVER'S HANDBOOK of 80 pages. Single copies of the JOURNAL or HANDBOOK are 25 cents, postpaid. In quantities of 10 or more copies, the price is 20 cents a copy.

Membership is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00. Publications are sent free to all members or may be subscribed for separately. Applications for membership or publications may be made to the General Secretary, 198 College St., Toronto.

The year 1940 also marks the hundredth anniversary of the founding in Toronto of the first Observatory (magnetic) in Canada. This was one of the first magnetic observatories in the world and became the nucleus of observatory development in Canada.

To mark the semi-centennial of the founding of our Society and the centenary of the founding of the first observatory, our Society plans to hold a special meeting in Toronto in the late summer. It is also planned to publish as a feature of the JOURNAL, articles and early documents dealing with the histories of the observatory and of the society.

The Society has for Sale:

Reprinted from the JOURNAL of the Royal Astronomical Society, 1936-1939.

The Physical State of the Upper Atmosphere, by B. Haurwitz, 96 pages; Price 50 cents postpaid.

The Small Observatory and its Design, by H. Boyd Brydon, 48 pages; Price 25 cents postpaid.

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